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RESEARCH ARTICLE

Development of a scale for factors causing delays in infrastructure projects in India

J.C. Edison[1], Harish Kumar Singla[2*]

[1] School of General Management, National Institute of Construction Management and Research, 25/1, Near NIA post office, Balewadi, Pune-411045, India, Contact-edisonjolly@gmail.com

[2] School of General Management, National Institute of Construction Management and Research, 25/1, Near NIA post office, Balewadi, Pune-411045, India, Contact-hsingla25@gmail.com

***Corresponding author:** Harish Kumar Singla, School of General Management, National Institute of Construction Management and Research, 25/1, Near NIA post office, Balewadi, Pune-411045, India, Contact-hsingla25@gmail.com

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Abstract

The objective of the paper is to develop a validated scale to measure the factors that cause delays in infrastructure projects. The study employed a standard three phase scale development procedure of Churchill (1979) which was augmented subsequently by Nunnally, Bernstein and Berge (1994) and Prakash and Phadtare (2018). In phase one, 73 factors that cause delays were identified, which were reduced to 45 based on literature review and expert opinions. These 45 factors were subjected to an exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) in phase two and three, respectively, to refine and establish convergent, discriminant and nomological validity of the scale. The study confirms that delays in infrastructure projects happen due to six factors, i.e., Contractor Related Factors (CON); Consultant Related Factors (CS); External Factors (EX); Labour Related Factors (LR); Material Related Factors (MT) and Design Related Factors (DJ). The study is particularly useful for the firms engaged in the development of infrastructure projects globally, as it identifies and ranks the factors that cause delays in a project. However, the study being confirmatory in nature only confirms the grouping of factors causing delays and is also limited by the possibility of sampling error.

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Keywords:

Infrastructure construction; Exploratory factor analysis, Confirmatory factor analysis; Delay; Cost Overrun.

Introduction

Construction is an essential component of economic growth and development. The increased spending in the construction sector acts as a stimulant to economic growth. It provides infrastructure capital. Further, through its backward and forward linkages with other sectors as well as through multiplier effect, it generates further investments and creates employment. Earlier studies have established a positive relationship between the share of construction in gross domestic product and the level of per capita income (Turin, 1973; Wells, 1986). Construction economists such as Jackman (2010), Myers (2008), Tan (2002), Hillebrandt (2000), Bon (1992), Wells (1986) and Turin (1978) emphasized the significance of the construction sector in economic growth.

However, the construction industry is one of the riskiest sectors due to fierce competitive bidding between multitudes of parties. This results in low margins along with time and cost over-runs (Jha and Devaya, 2008). Construction delays make the situation worse. Delays in a project can be defined as the time overrun either beyond completion date specified in a contract, or beyond the date that the parties agreed upon for delivery of a project (Assaf and Al-Hejji, 2006). According to Mahamid, Bruland and Dmaidi (2012), delays in construction project is a universal phenomenon across large and small projects, and in developed and developing nations. The delays in project execution result in extra costs and a reduction in financial returns. Delays in any form lead to a loss of revenue for clients and excess cost of overheads for the contractor. The success or failure of a project mostly depends on the timely delivery of the project to the client. A project delivered on time is likely to have less cost overruns and no loss on account of opportunity cost. Kumaraswamy and Chan (1998) found that if projects can overcome the situation of time overrun, it will lead to improved productivity.

The construction sector in India is growing. However, the projects in India are not immune to the problem of construction delays. Data drawn from the Centre for Monitoring Indian Economy (CMIE), India reveal that the total value of investments in such projects (both public and private) increased to INR 11,011 billion (USD 150 billion) in 2015-16 from INR 225 billion (USD 3 billion) in 2000-01. Further, the Ministry of Statistics and Programme Implementation (MOSPI) found that, out of 1453 projects as on April 2019, only 22 projects were ahead of schedule, 294 projects were on schedule and 388 projects were delayed. These reports further show an anticipated cost over-run of 17.9% in 2019 for the same projects[1]. The average cost overruns at 27% are even higher in United States and Europe (Flyvbjerg and Alexander Budzier, 2011).

Thus, time and cost overruns are a major problem affecting the project implementation globally. Extant research has given considerable attention to this problem and identified the factors causing delays in projects. However, a lot more is desired. The factors causing delays

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1 Government of India. (April 2019). Flash report on central sector projects (Rs.150 crore and above), Infrastructure and Project Monitoring Division, Ministry of Statistics and Programme Implementation, Government of India, New Delhi, p. 4.

can be country specific, project specific and location specific, hence it becomes very difficult to standardize these factors. It is observed that a lot of literature exists with respect to factors causing delays in projects. However, most of these studies restrict to identification of factors causing delay and rank them using relative importance index. Existing studies group these factors into categories such as client related, contractor and consultant related, material related, labour related, equipment related and external factors. However, such categorization is proposed purely based on experience/judgment. Few studies have gone beyond the experts' view and have conducted an exploratory factor analysis (EFA) to arrive at a statistically significant grouping for these factors. However; these studies have not validated the proposed groupings through confirmatory factor analysis (CFA). The current study presents a validated scale that groups the delay causing factors using EFA and then validates the same using CFA.

Literature Review

Several studies have been carried out by scholars to find the causes of delays in construction projects. The review of literature on project delays came across a series of remarkable empirical studies covering several countries. For example, Mansfield, Ugwu and Doran (1994) explored the causes of delay and cost overrun by taking client, consultant and contractors into consideration. They found that shortage of material, poor project monitoring and control and poor contract management are the most important causes of time and cost overrun agreed by the stakeholders of a project.

Ogunlana, Promkuntong and Vithool (1996) conducted a study in Thailand on the delays in building projects. They found that shortages and inadequacies in industry infrastructure, flaws of clients, consultants, and incompetence of contractors are some of the major causes of delay. Further, the conflicts between owners and other parties, poor site management and supervision have been found to be the key factors causing delay in projects (Satyanarayana and Iyer, 1996; Iyer and Jha, 2005).

Chan and Kumaraswamy (1997) evaluated the relative importance of 83 potential delay factors in construction projects in Hong Kong. They found insufficient risk management and supervision, unanticipated site conditions, slow decision making, variations initiated by client, and work variations as the major delay factors. A variation in the perception of different groups of participants in construction was observed with respect to causes of delays. Their study opined that bias of different industry groups might directly put the blame for delays on other parties.

Bordoli and Baldwin (1998) examined the factors affecting delays in building projects in the United States. They found that weather conditions, labour supply and sub-contractors were the major issues that cause of delays. Al-Momani (2000) studied causes of delay in 130 public projects in Jordan and established its strong relationship with failure and ineffective performance of contractors.

Odeh and Battaineh (2002) in their study identified the major causes of construction project delays. They assessed the relative importance of these causes for the traditional type of contracts from the point of view of construction contractors and consultants. The study indicated that owner intervention, slow decision making, inadequate contractor experience, financing and payments, labour productivity, inappropriate planning, and subcontractors were the most important causes of delay in construction projects.

The studies of Flyvbjerg et al. (2002, 2003 and 2004) revealed that infrastructure projects often suffer from delays and cost overruns. Alaghbari et al. (2007) in their study in Malaysia found that financial problems and co-ordination problems are the most important factors that cause delays in construction projects in Malaysia. Assaf and Al-Hejji (2006) in a study in Saudi Arabia found that shortage of labour, low productivity of labour, poor site management and supervision are the most critical factors affecting delays from contractor's perspective. Ernawati et al. (2007) found that in Malaysian construction industry the critical reasons for delay were financial problems, poor site management, delay in the delivery of materials to the site, and coordination problem.

Fugar and Agyakwah-Baah (2010) investigated the causes of delays of building construction projects in Ghana. The overall results indicated that the financial factors are the most important among the major factors causing construction project delays in Ghana. While Fugar and Agyakwah-Baah (2010) found delay in honouring certificates, underestimation of cost of project, poor project management plan, shortage of material and 32 other factors to be the major contributors to delays.

Doloi et al. (2011) identified 45 critical items causing delays in construction projects in India. The focus of the paper was more on project management issues rather than construction issues. Based on the EFA, they reduced these 45 items to seven factors namely: lack of commitment, inefficient site management, poor site coordination, improper planning, lack of clarity in project scope, lack of communication and Sub-standard contract.

Mahamid, Bruland and Dmaidi (2012) investigated the road construction projects in Palestine (West Bank) to discover the causes of delays and their severity. The study identified following delay causes: (i) political situation; (ii) segmentation of the West Bank and limited movement between areas; (iii) award project to lowest bid price; (iv) progress payment delay by owner; and (v) shortage of equipment as top five severe delay causes.

Fallahnejad (2013) identified and ranked the causes of delay in gas pipeline projects in Iran. The study found ten major delay factors: (i) imported materials; (ii) unrealistic project duration; (iii) client-related materials; (iv) land expropriation; (v) change orders; (vi) contractor selection methods; (vii) payment to contractor; (viii) obtaining permits; (ix) suppliers; and (x) contractor's cash flow.

González et al. (2014) analysed the causes of activity delays and time performance in construction projects. The study provided a methodology to check the qualitative (delay causes) and quantitative (time performance) dimensions of the delay issue.

Santoso and Soeng (2016) analysed the delay factors in road construction projects in Cambodia and found that poor site arrangement, management, and supervision, poor qualifications of the contractor's technical staff and project team, and frequent equipment breakdown are some of the key factors. Aziz and Abdel-Hakam (2016) studied delay causes of road construction projects in Egypt and found that financial problems, shortages in equipment, construction materials, skilled operators, inadequate experiences, reworks, changes or errors in design, delays in design submittal, soil and underground problems in investigation or management or expropriation, and physical obstructions are some of the reasons for delay. Kalidindi (2016) identified the factors that cause delay in the relocation of utilities on 11 road and bridge projects in India. Slow response from utility agencies, difficulty in identification of underground utilities, lack of information on underground utilities and conflict between agencies were some of the critical factors affecting delay. In a recent research, Gebrehiwet and Luo (2017) ranked 52 factors causing delays in Ethiopian construction projects and found that corruption and unavailability of utilities at site are the prime factors followed by price increases in materials and late design and design documents to name a few.

Alfakhri et al. (2018) developed a structural equation model and identified eight factors that cause delay, i.e., contractor, owner, consultant, utility service, government regulation, project, external factors, and equipment and material. Wang et al. (2018) investigated the causes of delays in building construction projects in China and reported that causes of variations, delays in progress payments, exceptionally low bids and subcontractors' poor performance and communication issues were the most important causes of delays in China. Ansah and Sorooshian (2018) proposed a theoretical framework, the 4P project delays, grouping them based on their shared characteristics. Adam, Josephson and Lindahl (2017) conducted a literature analysis to provide an aggregated ranking of project delays, which was limited to 40 journal articles reporting delays in publicly funded construction projects. Agyekum-Mensah and Knight (2017) through 41 interviews identified 32 themes, which were grouped into 15 categories of causes of delays in the construction projects. These included knowledge and competence shortage, poor commercial decisions, unnecessary health and safety restrictions, poor risk management and poor space and logistics management. Recently, Durdyev and Hosseini (2019) in an extensive literature review identified 149 factors that cause delays and the ten most common causes were reported as weather/climate conditions, poor communication, lack of coordination and conflicts between stakeholders, ineffective or improper planning, material shortages, financial problems, payment delays, equipment/plant shortage, lack of experience/qualification/competence among project stakeholders, labour shortages and poor site management.

Of course, there are many studies that discuss the factors causing delays in different types of construction projects globally. Most of these studies have used a survey-based approach to collect data from respondents and used relative importance index as a major tool to rank the factors causing delays. It is important to note that most of these studies have examined individual items that caused delays in a project and then went on to group them on the basis of their own experience/judgment rather than using a statistical measure. Off late, in few cases, EFA has been used to reduce the number of items into groups, however, attempt to confirm the groupings and develop a validated scale are almost non-existent. Hence, the authors feel a need to develop the standardized and validated scale by grouping the items that cause delays in an infrastructure project.

Research Method

As, the objective of the study was to develop a scale; the study employed the standard three stage scale development procedure of Churchill (1979) which was augmented subsequently by Nunnally, Bernstein and Berge (1994), and Prakash and Phadtare (2018). In Phase 1, a qualitative inquiry was conducted to generate and select items causing delays in a project based on the literature and expert opinion sought from industry and academia.

Phase 2 dealt with refinement of scale using EFA and reliability analysis. For this, a comprehensive questionnaire was developed which was divided into two sections. While, section 1 sought demographic information of the respondents and project details, section 2 contained a list of 45 items that caused delay in projects. The respondents were asked to rate these items on a five point scale, where 1 represented "No effect on time schedule", 2 represented "Little effect on time schedule", 3 means "Moderate effect on time schedule", 4 represented "Significant effect on time schedule" and 5 means "Extreme effect on time schedule". A non-probabilistic snowball sampling method was adopted, and more than 450 respondents were approached, of which 189 useful responses were obtained, giving a response rate of 42%.

Phase 3 was about scale validation for which CFA was used to establish the convergent, discriminant and nomological validity. In phase 3 again, the non-probabilistic snowball sampling method was adopted and approximately 300 respondents were approached, of which 129 useful responses were obtained, corresponding to a response rate of 43 %.

For both phase 2 and 3, the target respondents included project managers, site supervisors, project management consultants, design consultants and architects, as all these parties are directly or indirectly involved in project planning and execution and are in a better position to explain and rate the factors that cause delay. Table I depicts the profile of these respondents in Phase 2 and Phase 3.

Table I Demographic Profile of Respondents

Description	First Phase	Second Phase
Total Respondents	189 (100%)	129 (100%)
Education		
Graduate	45(23.80%)	28(21.70%)
Postgraduate	131(69.30%)	93(72.10%)
Doctorate	13(06.90%)	8(06.20%)
Age		
Less than 35 years	55(29.10%)	41(31.80%)
35-45 years	71(37.55%)	52(40.30%)
45-60 years	52(27.50%)	33(25.60%)
60 years and above	11(05.85%)	03(02.30%)
Gender		
Male	167(88.35%)	118(91.50%)
Female	22(11.65%)	11(08.50%)
Project Size (In INR)		
100 Billion and above	11(05.80%)	08(06.20%)
10 to 99 Billion	31(16.40%)	26(20.10%)
01 to 09 Billion	24(12.70%)	18(14.00%)
Below 1 Billion	85(45.00%)	69(53.50%)
Did not disclose	38(20.10%)	08(06.20%)
Experience		
Less than 5 years	54(28.60%)	38(29.50%)
5-10 years	92(48.70%)	57(44.20%)
More than 10 years	43(22.07%)	34(26.30%)

Source: Authors Compilation

Data Analysis

PHASE: 1 GENERATION OF LIST OF FACTORS THAT CAUSE DELAY AND EXPERT OPINION

As discussed in research methodology, a list of 73 factors that caused delay was created based on the review of literature (Annexure 1). This list was put in front of five specialists in the field of construction management. Two of these experts were academicians and three were from the industry. The academicians had more than 25 years of experience in teaching and research in construction management. Each industry expert had a work experience of more than 20 years; and had worked on complex infrastructure projects in India and abroad. These experts first reviewed the items individually and later were invited for a panel discussion. They eliminated some of the items that were repetitive or had similar meaning, modified the sentence formation. Based on their discussion, the items were reduced to 45.

PHASE: 2 EXPLORATORY FACTOR ANALYSES (REFINEMENT OF SCALE)

A comprehensive questionnaire was furnished to the respondents' group and EFA was applied using principal component analysis and Varimax rotation in SPSS 21. There are several ways to extract the factors, however, principle component analysis (PCA) was considered most appropriate. As recommended, when the objective is to summarize most of the original information (Variance) in a minimum number of factors for prediction purpose, PCA is very useful (Hair et al., 2010).

Kaiser-Meyer-Olkin (KMO) test, which is a measure of sampling adequacy resulted in a test value of 0.81, which is above the minimum desired level of 0.70 (Hair et al., 2010). Bartlett's Test of Sphericity was conducted to test the presence of correlations among items which resulted in the Chi-Square value of 1557.25, degree of freedom=325 and Significance=0.00, hence, it was concluded that there exist a correlation among items.

The results of EFA are presented in Table II. Nineteen items were dropped after initial results of EFA due to either low communalities value (the common or shared variance of an item with all the other items in the analysis, for which the cut off used in the study is 0.50; Hair et al., 2010); low value of MSA (the cut off used in the study is 0.50; Hair et al., 2010); low factor loadings (an item is not correlated to the factor for which the cut off used is 0.40; Hair et al., 2010) and due to cross loadings (an item is loading in more than one factor). The remaining 26 items had an MSA and communalities above the desired cut off level of 0.50, the factor loadings of above 0.40 and they were not cross loaded. Therefore, these items were retained in the study. The Eigen value criterion (Cut off value=1.00; Hair et al., 2010) was used in the study to extract the number of factors. Eigen value explains the variance of at least one single item, if it is to be retained for interpretation. EFA resulted in extraction of six factors shown in Table II. These factors are named as "Contractor Related Factors", "Consultant Related Factors", "External Factors", "Labour Related Factors", "Material Related Factors" and "Design Related Factors". These factors can be ranked from one to six based on the percentage variance explained.

Nunnally (1994) and Hair et al. (2010) suggested that in order to establish the reliability of these factors, the value of Cronbach's Alpha must be at least above 0.60. A value between 0.60-0.70 indicates average reliability and a value above 0.70 indicates high reliability. The results in Table III indicate that the reliability of all factors is above average.

Table II Results of EFA

Items	Code	MSA	Communalities	Factor Loading	% Variance Explained (Eigen Value)	Cronbach's Alpha
Contractor Related Factors (CON)						
Poor site management and supervision by contractor	CON5	0.84	0.66	0.80	11.70 (5.87)	0.81
Poor communication & coordination by contractor with other parties	CON6	0.83	0.60	0.75		
Ineffective planning and scheduling of project by contractor	CON7	0.87	0.57	0.72		
Improper construction methods implemented by contractor	CON8	0.80	0.60	0.66		
Poor qualification of the contractors' technical staff	CON12	0.85	0.57	0.68		
Consultant Related Factors (CS)						
Inflexibility (rigidity) of consultant	CS3	0.79	0.57	0.71	9.77 (2.71)	0.75
Poor communication/ co-ordination between consultant & other parties	CS4	0.75	0.59	0.71		
Late in reviewing and approving design documents by consultant	CS5	0.72	0.63	0.77		
Inadequate experience of consultant	CS7	0.81	0.49	0.61		
External Factors (EX)						
Effects of subsurface conditions (e.g., soil, high water table, etc.)	EX1	0.74	0.53	0.72	9.37 (2.18)	0.67
Delay in obtaining permits from municipality	EX2	0.82	0.65	0.64		
Rain effect on construction activities	EX4	0.82	0.66	0.61		
Unavailability of utilities in site (like water, electricity, telephone, etc.)	EX5	0.82	0.60	0.69		
Traffic control and restriction at job site	EX7	0.83	0.61	0.59		

Table II continued

Items	Code	MSA	Communalities	Factor Loading	% Variance Explained (Eigen Value)	Cronbach's Alpha
Labour Related Factors (LR)						
Unqualified workforce	LB2	0.82	0.49	0.66	9.15 (1.56)	0.70
Nationality of labourers	LB3	0.84	0.50	0.63		
Low productivity level of labourers	LB4	0.72	0.53	0.77		
Personal conflicts among labourers	LB5	0.79	0.56	0.73		
Material Related Factors (MT)						
Shortage of construction materials in market	MT1	0.81	0.55	0.74	9.12 (1.40)	0.65
Changes in material types and specifications during construction	MT2	0.85	0.70	0.59		
Delay in material delivery	MT3	0.79	0.61	0.67		
Damage of sorted material while they are needed urgently	MT4	0.84	0.60	0.69		
Design Related Factors (DJ)						
Delays in producing design documents	DJ2	0.84	0.52	0.62	8.61 (1.27)	0.71
Complexity of project design	DJ4	0.79	0.50	0.80		
Insufficient data collection and survey before design	DJ5	0.84	0.60	0.69		
Misunderstanding of owners' requirements by design engineer	DJ6	0.81	0.53	0.61		

Source: Authors Compilation

Note: Rotation converged in 6 iterations. Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.

PHASE 3: CONFIRMATORY FACTOR ANALYSIS (SCALE VALIDATION)

After scale refinement, in order to establish the validity of the factors extracted through EFA, a second stage survey was done, and the data was analysed using CFA. Table III shows the results of factor loadings, Cronbach's alpha and % variance explained through CFA.

Table III MSA, factor loadings and Communality of Second Phase Survey

Variable	MSA	Communalities	Factor Loading	% Variance Explained (Eigen Value) {Rank of Factor}	Cronbach's Alpha
CON5	0.861	.675	.796	12.00 (5.76) {Rank One}	0.822
CON6	0.782	.677	.796		
CON7	0.755	.646	.731		
CON8	0.732	.651	.653		
CON12	0.801	.588	.674		
CS3	0.641	.594	.745	10.26 (2.78) {Rank Two}	0.763
CS4	0.639	.610	.728		
CS5	0.622	.638	.784		
CS7	0.719	.526	.690		
EX1	0.695	.627	.689	10.10 (1.99) {Rank Three}	0.715
EX2	0.728	.510	.591		
EX4	0.740	.497	.610		
EX5	0.826	.595	.665		
EX7	0.792	.551	.656		
LB2	0.839	.584	.691	9.81 (1.68) {Rank Four}	0.771
LB3	0.800	.612	.593		
LB4	0.757	.646	.735		
LB5	0.731	.691	.806		
MT1	0.817	.622	.693	8.73 (1.32) {Rank Six}	0.705
MT2	0.813	.585	.716		
MT3	0.751	.588	.738		
MT4	0.781	.645	.594		
DJ2	0.781	.448	.588	9.25 (1.49) {Rank Five}	0.729
DJ4	0.685	.682	.811		
DJ5	0.831	.618	.635		
DJ6	0.777	.579	.660		

Source: Authors Compilation

A factor loading of 0.50 or greater is considered good for sample size up to 150 for CFA (Hair et al., 2010). All the factor loadings are above 0.50 as reported in Table III. A measurement model was developed using AMOS 18.0 and maximum likelihood method was used for estimation. The results of CFA are presented in Table IV to VI. Table IV indicates that the measurement model is a good fit. The desirable value for X^2/df is between 1.00-3.00. A smaller value (<1.000) can indicate over fitted model, while a higher value (>3.000) can indicate an under parameterized model (Prakash and Phadtare, 2018). However, Carmines and McIver (1981) and Malodia et al. (2017) suggested that X^2/df criteria was sensitive to large sample size, therefore, they choose to ignore this measure. The values of comparative fit index (CFI=0.891), and Tucker Lewis index (TLI=0.876) are acceptable. Hair et al. (2010), Prakash et al. (2011) and Prakash and Phadtare (2018) suggested accepting the model as moderate fit for CFI and TLI values above 0.80 and good for values above 0.90. The root mean square error of approximation (RMSEA) is another important fit static that describes how parsimoniously the proposed model fits with the population covariance matrix. Steiger (1990 and 2007), recommended RMSEA value within 0.10, however, Browne and Cudeck (1993) suggested RMSEA value of 0.05 or below as an indicator of close fit. Later, it was argued by Hair et al. (2014), MacCallum, Browne and Sugawara (1996) Prakash et al. (2011) and Prakash and Phadtare (2018) that RMSEA any value between 0.10 and 0.08 indicates an average fit and values below 0.08 may be considered as good fit. The value of RMSEA in the study is 0.054, which is excellent fit. The value of Standardized Root Mean Square Residual (SRMR=0.073) is also indicating excellent fit. Further, Hu and Bentler (1999) noted that it was difficult to designate a specific cut-off value for each fit index and recommend the use of combinational rules. Therefore, based on combining rules criteria, the study concludes that the model is a good fit.

It is important to establish the convergent validity, discriminant validity and reliability of the measurement model. This was done using standardized residuals and correlations, factor loadings and modification indices. For establishing convergent validity, the desired value of composite reliability (CR), average variance extracted (AVE) and MaxR(H) is 0.700, 0.500 and 0.800 respectively (Hancock and Mueller, 2001; Hair et al., 2010). Further CR>AVE is a condition to be met. As evident from the results in Table V, the values of CR and MaxR(H) are close to or above the desired level, and CR>AVE in all cases, the value of AVE is below 0.5. However, Malhotra and Dash (2011) argue that AVE is often too strict a measure, and reliability can be established through CR alone. In order to establish discriminant validity, both maximum shared variance (MSV) and average shared variance (ASV) should be less than that of AVE (Bagozzi, Yi and Phillips, 1991; Hair et al., 2010). Table V shows that this criterion (ASV<AVE) is also met. Nomological validity of the constructs is supported by the fact that all estimates of regression are significant at 0.001 (Hair et al., 2010) (Table VI). Hence, it can be concluded that convergent validity, discriminant validity and reliability of the scale is established.

Table IV Model Fit Measures

Measure	Estimate	Threshold	Interpretation
Chi Square	389.214	--	--
DF	284	--	--
Chi Square/DF	1.37	Between 1 and 3	Excellent
CFI	0.891	>0.95	Acceptable
TLI	0.876	>0.95	Acceptable
SRMR	0.073	<0.08	Excellent
RMSEA	0.054	<0.06	Excellent
PClose	0.312	>0.05	Excellent

Source: Authors Compilation

Table V Model Validity Measures

Latent Construct	CR	AVE	MSV	ASV	MaxR(H)	MT	CON	CS	EX	LB	DJ
Contractor Related Factors	0.757	0.441	0.323	0.126	0.774	0.664					
Consultant Related Factors	0.823	0.483	0.294	0.095	0.828	0.402	0.695				
External Factors	0.764	0.449	0.216	0.177	0.769	0.314	0.087	0.67			
Labour Related Factors	0.717	0.339	0.277	0.182	0.724	0.489	0.242	0.291	0.582		
Material Related Factors	0.771	0.457	0.294	0.202	0.772	0.436	0.542	0.261	0.526	0.676	
Design Related Factors	0.727	0.410	0.323	0.192	0.775	0.568	0.331	0.465	0.48	0.29	0.64

Source: Authors Compilation

Table VI Regression weights

Regression			Estimate	S.E.	C.R.	P
CON5	<---	CON	1			
CON6	<---	CON	0.758	0.122	6.217	***
CON7	<---	CON	0.992	0.137	7.218	***
CON8	<---	CON	0.981	0.136	7.242	***
CON12	<---	CON	0.994	0.152	6.561	***
CS3	<---	CS	1			
CS4	<---	CS	1.081	0.194	5.574	***
CS5	<---	CS	1.131	0.199	5.673	***
CS7	<---	CS	0.952	0.175	5.433	***
EX1	<---	EX	1			
EX2	<---	EX	0.913	0.204	4.474	***
EX4	<---	EX	0.894	0.205	4.367	***
EX5	<---	EX	1.11	0.218	5.085	***
EX7	<---	EX	1.153	0.228	5.059	***
LB2	<---	LB	1			
LB3	<---	LB	0.941	0.151	6.241	***
LB4	<---	LB	0.971	0.153	6.351	***
LB5	<---	LB	0.944	0.153	6.159	***
MT1	<---	MT	1			
MT2	<---	MT	0.736	0.113	6.523	***
MT3	<---	MT	0.692	0.124	5.584	***
MT4	<---	MT	0.77	0.121	6.357	***
DJ2	<---	DJ	1			
DJ4	<---	DJ	1.337	0.326	4.096	***
DJ5	<---	DJ	1.991	0.426	4.671	***
DJ6	<---	DJ	1.596	0.356	4.486	***

Source: Authors Compilation

***Significant

Discussion

The study was conducted with the sole objective to develop a validated measurement scale for factors that caused delay in infrastructure projects. The results of the study confirmed that delays in a project happen due to six factors ranked in the order of importance of 1-6.

1. Contractor Related Factors (CON)
2. Consultant Related Factors (CS)
3. External Factors (EX)
4. Labour Related Factors (LR)
5. Design Related Factors (DJ)
6. Material Related Factors (MT).

Contractor related factors (CON) include poor site management and supervision by contractor, poor communication and coordination by contractor with other parties, ineffective planning and scheduling of project by contractor, improper construction methods implemented by contractor, poor qualification of the contractor's technical staff. Consultant related factors (CS) include inflexibility (rigidity) of consultant, poor communication/co-ordination between consultant and other parties, delay in reviewing and approving design documents by consultant, inadequate experience of consultant. External factor (EX) are effects of subsurface conditions (e.g., soil, high water table, etc.), delay in obtaining permits from municipality, rain effect on construction activities, unavailability of utilities in site (like water, electricity, telephone, etc.), traffic control and restriction at job site. Labour related factors (LR) are unqualified workforce, nationality of labourers, low productivity level of labourers, and personal conflicts among labourers. Material related factors (MT) are shortage of construction materials in market, changes in material types and specifications during construction, delay in material delivery, damage of sorted material while they are needed urgently and Design related factors (DJ) are delays in producing design documents, complexity of project design, insufficient data collection and survey before design and misunderstanding of owners requirements by design engineer. The resulted scale is refined and validated using a standard scale development procedure.

The study confirms the categorizations proposed by Assaf and Al-Hejji (2006); Alaghbari et al. (2007); Sambasivan and Soon (2007); Aziz and Abdel-Hakam (2016); Santoso and Soeng (2016); Gebrehiwet and Luo (2017); Wang et al. (2018) and Alfakhri et al. (2018) to a great extent. However, the current study did not find owner/client related factors as the major cause of delay in infrastructure projects in India, which is a major deviation from the past. The reason for this can be the inherent bias in the respondents' profile as most of the respondents were working with contractor and consultation companies rather than owners.

Conclusion

CONTRIBUTION

The study contributes to the body of knowledge by proposing a refined and validated scale which can be a useful measure in all infrastructure projects. This scale can guide the project authorities in prioritizing the risk in projects (as a ranking of the factors is also given). As the study is presenting a standard methodology, it can be tested globally and extended further. Therefore, the scale development and proposing a standard methodology is the major contribution of this study.

IMPLICATIONS

Even though the study is conducted in India, the implications are global. Despite, improvements in construction productivity, innovations in terms of material and technology, infrastructure projects continue to suffer from the problem of the time overrun. Some of the causes for these overruns may be unique and project specific, while the others may be country specific. These factors depend on the culture, geography, and political and legal systems of the country. The factors identified in this paper are labour and material related issues, contractor related issues and external factors. They are applicable globally and important to all infrastructure projects. Hence, the study is very useful for the firms engaged in development of infrastructure projects globally, as it identifies and ranks the factors that cause delays in a project. The firms engaged in infrastructure projects must examine these factors carefully in order to reduce delay in infrastructure projects. Further, the study is also important and path breaking from an academic point of view as it presents a validated scale to figure out the factors causing delay in infrastructure projects. The project members must ensure proper site management and supervision to ensure that the projects are delivered on time. At the same time, proper coordination and communication with each stakeholder along with effective planning and scheduling, recruiting qualified technical staff can help reduce the delays. The firms must also employ adequate and trained labour to ensure that the projects run smoothly. In order to endure that there is never a shortage of material, proper inventory management must be done at site. There are some factors that are beyond control of the project team such as subsurface conditions (e.g., soil, high water table, etc.), delay in obtaining permits from municipality, rain effect on construction activities, unavailability of utilities in site (like water, electricity, telephone, etc.), traffic control and restriction at job site, etc. However, if the project team can ensure proper management of all controllable areas, the project delivery can be on time without delay and it can lead to a lot of cost savings and sustained profitability.

LIMITATIONS AND FUTURE DIRECTION

Despite all efforts, the study has few limitations. The researchers cannot rule out the possibility of respondent's bias as well as the sampling error, because of the two-stage sampling procedure. However, despite the limitations, the results of the study have academic and industry relevance and researchers in future can also use this scale and may test its validity in different circumstances. They may also modify it for the purpose of theory building.

References

Adam, A., Josephson, P.-E.B. and Lindahl, G., 2017. Aggregation of factors causing cost overruns and time delays in large public construction projects: trends and implications. *Engineering, Construction and Architectural Management*, 24(3), pp.393-406. https://doi.org/10.1108/ecam-09-2015-0135

Agyekum-Mensah, G. and Knight, A.D., 2017. The professionals' perspective on the causes of project delay in the construction industry. *Engineering, Construction and Architectural Management*, 24(5), pp.828-41. https://doi.org/10.1108/ecam-03-2016-0085

Alaghbari, W., Kadir, M.R.A., Salim, A. and Ernawati, M.K., 2007. The significant factors causing delay of building construction projects in Malaysia. *Engineering, Construction and Architectural Management*, 14(2), pp.192-206. https://doi.org/10.1108/09699980710731308

Alfakhri, A.Y.Y., Ismail, A., Khoiry, M.A., Albrka, S.I., Alshetwi, A.B.Z. and Alghadi, M.S., 2018. A Study of Identifying Significant Variables of Delays in Road Construction Via Structural Equation

Modelling (SEM). *International Journal of Engineering & Technology*, 7, pp.893-98. https://doi.org/10.14419/ijet.v7i2.29.14278

Al-Momani, H.A., 2000. Construction delay: a quantitative analysis. *International Journal of Project Management*, 18(1), pp.51-59. https://doi.org/10.1016/s0263-7863(98)00060-x

Ansah, R.H. and Sorooshian, S., 2018. 4P delays in project management. *Engineering, Construction and Architectural Management*, 25(1), pp.62-76. https://doi.org/10.1108/ecam-09-2016-0199

Assaf, S.A. and Al-Hejji, S., 2006. Causes of delay in large construction projects. *International Journal of Project Management*, 24, pp.349–57. https://doi.org/10.1016/j.ijproman.2005.11.010

Aziz, R.F. and Abdel-Hakam, A.A., 2016. Exploring delay causes of road construction projects in Egypt. *Alexandria Engineering Journal*, 55, pp.1515–39. https://doi.org/10.1016/j.aej.2016.03.006

Bagozzi, R.P., Yi, Y. and Phillips, L.W., 1991. Assessing construct validity in organizational research. *Administrative Science Quarterly*, 36(3), pp.421-58. Bagozzi, R.P., Yi, Y. and Phillips, L.W., 1991. Assessing construct validity in organizational research. *Administrative Science Quarterly*, 36(3), pp.421-58.

Bon, R., 1992. The future of international construction: Secular patterns of growth and decline. *Habitat International*, 16(3), pp.119. https://doi.org/10.1016/0197-3975(92)90068-a

Bordoli, D.W. and Baldwin, A.N., 1998. A methodology for assessing construction project delays. *Journal of Construction Management and Engineering*, 16(3), pp.327–37. https://doi.org/10.1080/014461998372358

Browne, M. W. and Cudeck, R., 1993. Alternative ways of assessing model fit. *Sage Focus Editions*, 154, p.136.

Carmines, E.G. and McIver, J.P., 1981. Analyzing models with unobserved variables. In G.W. Bohrnstedt and E.F. Borgatta, eds. *Social Measurement: Current Issues*. Beverly Hills, CA: Sage, pp.65-115.

Chan, D.W.M and Kumaraswamy, M.M., 1997. A comparative study of causes of time overruns in Hong Kong construction projects. *International Journal of Project Management*, 15(1), pp.55-63. https://doi.org/10.1016/s0263-7863(96)00039-7

Churchill, G.A. Jr., 1979. A paradigm for developing better measures of marketing constructs. *Journal of Marketing Research*, 16(1), pp.64-73. https://doi.org/10.2307/3150876

Doloi, H., Sawhney, A., Iyer, K.C. and Rentala, S., 2011. Analysing factors affecting delays in Indian construction projects. *International Journal of Project Management*, 30, pp.479-89. https://doi.org/10.1016/j.ijproman.2011.10.004

Durdyev, S. and Hosseini, M.R., 2019. Causes of delays on construction projects: a comprehensive list. *International Journal of Managing Projects in Business*, 13(1), pp.20-46. https://doi.org/10.1108/ijmpb-09-2018-0178

Ernawati, S., Mohd., A., Razali, A. and Azizah, K., 2007. The significant factors causing delay of building construction projects in Malaysia. *Engineering, Construction and Architectural Management*, 14(2), pp.192-206. https://doi.org/10.1108/09699980710731308

Fallahnejad, M.H., 2013. Delay causes in Iran gas pipeline projects. *International Journal of Project Management*, 31(1), pp.136–46. https://doi.org/10.1016/j.ijproman.2012.06.003

Flyvbjerg, B. and Budzier, A., 2011. Why your IT project may be riskier than you think. *Harvard Business Review*, September, pp.601–03.

Flyvbjerg, B., Holm, M.K.S. and Buhl, S.L., 2002. Underestimating costs in public works projects error or lie? *Journal of the American Planning Association*, 68(3), pp.279-95. https://doi.org/10.1080/01944360208976273

Flyvbjerg, B., Holm, M.K.S. and Buhl, S.L., 2003. How common and how large are cost overruns in transport infrastructure projects? *Transport Reviews*, 23(1), pp.71-88. https://doi.org/10.1080/01441640309904

Flyvbjerg, B., Holm, M.K.S. and Buhl, S.L., 2004. What causes cost overrun in transport infrastructure projects? *Transport Reviews*, 24(1), pp.3-18. https://doi.org/10.1080/0144164032000080494a

Fugar, F.D. and Agyakwah-Baah, A.B., 2010. Delays in building construction projects in Ghana. *Australasian Journal of Construction Economics and Building*, 10(1–2), pp.103–16. https://doi.org/10.5130/ajceb.v10i1-2.1592

Gebrehiwet, T. and Luo, H., 2017. Analysis of Delay Impact on Construction Project Based on RII and Correlation Coefficient: Empirical Study. *Procedia Engineering*, 196(2017), pp.366-74. https://doi.org/10.1016/j.proeng.2017.07.212.

González, P., González, V., Molenaar, K. and Orozco, F., 2014. Analysis of causes of delay and time performance in construction projects. *Journal of Construction Engineering and Management*, 140(1), pp.3-6. https://doi.org/10.1061/(asce)co.1943-7862.0000721

Government of India, 2019. *Flash report on central sector projects (Rs.150 crore and above)-April 2019*. New Delhi: Infrastructure and Project Monitoring Division, Ministry of Statistics and Programme Implementation, Government of India, p.4.

Hair, F. Jr, J., Sarstedt, M., Hopkins, L. and G. Kuppelwieser, V., 2014. Partial least squares structural equation modeling (PLS-SEM). *European Business Review*, 26(2), pp.106-21. https://doi.org/10.1108/ebr-10-2013-0128

Hair, J., Black, W., Babin, B.Y.A., Anderson, R., and Tatham, R., 2010. *Multivariate Data Analysis, A Global Perspective*. New Jersey, NJ: Pearson Prentice Hall.

Hancock, G.R., Mueller, R.O., 2011. The reliability paradox in assessing structural relations within covariance structure models. *SAGE*, 71(2), pp.306-24. https://doi.org/10.1177/0013164410384856

Hillebrandt, P.M., 2000. *Economic theory and the construction industry*. 3rd. ed. London: Macmillan Press Ltd.

Hu, L. and Bentler, P.M., 1999. Cut-off criteria for fit indexes in covariance structure analysis: conventional criteria versus new alternatives. *SEM*, 6(1), pp.1-55. https://doi.org/10.1080/10705519909540118

Iyer, K.C. and Jha, K.N., 2005. Factors affecting cost performance: evidence from Indian construction projects. *International Journal of Project Management*, 23, pp.283–95. https://doi.org/10.1016/j.ijproman.2004.10.003

Jackman, M., 2010. Investigating the relationship between residential construction and economic growth in a small developing country: The case of Barbados. *International Real Estate Review*, 13(1), pp. 109-16.

Jha, N.K. and Devaya, M.N., 2008. Modeling the risks faced by Indian construction companies assessing international projects. *Construction Management and Economics*, 26(4), pp.337-48. http://dx.doi.org/10.1080/01446190801953281.

UTS ePRESS

Kalidindi, A.V.S.N., 2016. Interrelationships of factors causing delays in the relocation of utilities. *Engineering, Construction and Architectural Management*, 23(3), pp.349-68. http://dx.doi.org/10.1108/ECAM-10-2014-0127.

Kumaraswamy, M. and Chan, D., 1998. Contributors to construction delay. *Construction Management & Economics*, 16(1), pp.17–29. https://doi.org/10.1080/014461998372556

MacCallum, R. C., Browne, M.W. and Sugawara, H.M., 1996. Power analysis and determination of sample size for covariance structure modeling. *Psychological Methods*, 1(2), pp.130. https://doi.org/10.1037/1082-989x.1.2.130

Mahamid, I., Bruland, A. and Dmaidi, N. 2012. Causes of delay in road construction projects. *Journal of Management in Engineering*, 28(3), pp. 300-310. https://doi.org/10.1061/(asce)me.1943-5479.0000096

Malhotra N.K. and Dash S., 2011. *Marketing Research an Applied Orientation*. London: Pearson Publishing.

Malodia, S., Singh, P., Goyal, V. and Sengupta, A., 2017. Measuring the impact of brand-celebrity personality congruence on purchase intention. *Journal of Marketing Communications*, 23(5), pp.493-512. https://doi.org/10.1080/13527266.2017.1322125

Mansfield, N., Ugwu, O. and Doran, T., 1994. Causes of delay and cost overruns in Nigerian construction projects. *International Journal of Project Management*, 12, pp.254-60. https://doi.org/10.1016/0263-7863(94)90050-7

Myers, D., 2008. *Construction Economics*. 2nd. ed. London and New York: Taylor & Francis.

Nunnally, J.C., Bernstein, I.H. and Berge, J.M.T., 1994. *Psychometric Theory*. NY: McGraw-Hill.

Odeh, A.M. and Battaineh, H.T. 2002. Causes of construction delay: traditional contracts. *International Journal of Project Management*, 20, pp.67-73. https://doi.org/10.1016/s0263-7863(00)00037-5

Ogunlana, S.O., Promkuntong, K. and Vithool, J., 1996. Construction delays in a fast growing economy: comparing Thailand with other economies. *International Journal of Project Management*, 14(1), pp.37-45. https://doi.org/10.1016/0263-7863(95)00052-6

Prakash, A. and Phadtare, M., 2018. Service quality for architects: scale development and validation. *Engineering, Construction and Architectural Management*, 25(5), pp.670-86. https://doi.org/10.1108/ecam-03-2017-0046

Prakash, A., Mohanty, R.P., Kumar, S. and Kallurkar, S.P., 2011. Validation of multiple-item scale for measuring service quality in life insurance business: structural equation modelling approach. *International Journal of Productivity and Quality Management*, 8(4), pp.433-58. https://doi.org/10.1504/ijpqm.2011.043009

Sambasivan, M. and Soon, Y. W. 2007. Causes and effects of delays in Malaysian construction industry. *International Journal of Project Management*, 25(5), pp.517-526. https://doi.org/10.1016/j.ijproman.2006.11.007

Santoso, D.S. and Soeng, S., 2016. Analyzing Delays of Road Construction Projects in Cambodia: Causes and Effects. *Journal of Management in Engineering*, 32(6), pp.05016020-1-11. https://doi.org/10.1061/(asce)me.1943-5479.0000467

Satyanarayana, K.N. and Iyer, K.C., 1996. Evaluation of delays in Indian construction contracts. *Journal of the Institution of Engineers (India)*, 77, pp.14–22.

Steiger, J.H., 1990. Structural Model Evaluation and Modification: An Interval Estimation Approach. *Multivariate Behavioral Research*, 25(2), pp.173-80. https://doi.org/10.1207/s15327906mbr2502_4

Steiger, J.H., 2007. Understanding the limitations of global fit assessment in structural equation modeling. *Personality and Individual Differences*, 42(5), pp.893–98. https://doi.org/10.1016/j.paid.2006.09.017

Tan, W., 2002. Construction and economic development in selected LDCs: past, present and future. *Construction Management & Economics*, 20(7), pp.593. https://doi.org/10.1080/01446190210159827

Turin, D.A., 1978. Construction and Development. *Habitat International*, 3(1/2), pp.33-45. https://doi.org/10.1016/0197-3975(78)90032-2

Turin, D.A., 1973. *The Construction Industry: Its Economic Significance and Its Role in Development*, London: University College Environmental Research Group.

Wang, T., Ford, D.N., Heap-Yih Chong and Zhang, W., 2018. Causes of delays in the construction phase of Chinese building projects. *Engineering, Construction and Architectural Management*, 25(11), pp.1534-51. https://doi.org/10.1108/ecam-10-2016-0227

Wells, J., 1986. *The Construction Industry in Developing Countries: Alternative Strategies for Development*, London: Dover, N.H.: Croom Helm.

Annexure 1 Initial list of 73 factors

Factors Causing Delay
Owner Related
• Delay in progress payments by owner
• Delay to furnish and deliver the site to the contractor by the owner
• Change orders by owner during construction
• Late in revising and approving design documents by owner
• Delay in approving shop drawings and sample materials
• Poor communication & coordination by owner & other parties
• Slowness in decision making process by owner
• Conflicts between joint-ownership of the project
• Unavailability of incentives for contractor for finishing ahead of schedule
• Suspension of work by owner
Contractor Related
• Difficulties in financing project by contractor
• Conflicts in subcontractors' schedules in the execution of project
• Rework due to errors during construction
• Conflicts between contractor and other parties (consultant & owner)
• Poor site management and supervision by contractor
• Poor communication & coordination by contractor with other parties
• Ineffective planning and scheduling of project by contractor

Annexure 1 continued

Factors Causing Delay
• Improper construction methods implemented by contractor
• Delays in subcontractors' work
• Inadequate contractors work
• Frequent change of sub-contractors because of their inefficient work
• Poor qualification of the contractors' technical staff
• Delay in site mobilization
Consultant Related
• Delay in performing inspection and testing by consultant
• Delay in approving major changes in the scope of work by consultant
• Inflexibility (rigidity) of consultant
• Poor communication/co-ordination between consultant & other parties
• Late in reviewing and approving design documents by consultant
• Conflicts between consultant and design engineer
• Inadequate experience of consultant
Project Related
• Original contract duration is too short
• Legal disputes between various parts
• Inadequate definition of substantial completion
• Ineffective delay penalties
• Type of construction contract (Turnkey, construction only)
• Type of project bidding & award (negotiation, lowest bidder)
Design Related
• Mistakes and discrepancies in design documents
• Delays in producing design documents
• Unclear and inadequate details in drawings
• Complexity of project design
• Insufficient data collection and survey before design
• Misunderstanding of owners' requirements by design engineer
• Inadequate design-team experience
• Un-use of advanced engineering design software
Material Related
• Shortage of construction materials in market
• Changes in material types and specifications during construction
• Delay in material delivery

Annexure 1 continued

Factors Causing Delay
• Damage of sorted material while they are needed urgently
• Delay in manufacturing special building materials
• Late procurement of materials
• Late in selection of finishing materials due to availability of many types in market
• Equipment Related
• Equipment breakdowns
• Shortage of equipment
• Low level of equipment-operators skill
• Low productivity and efficiency of equipment
• Lack of high-technology mechanical equipment
Labour Related
• Shortage of labourers
• Unqualified workforce
• Nationality of labourers
• Low productivity level of labourers
• Personal conflicts among labourers
• External Factors
• Effects of subsurface conditions (e.g., soil, high water table, etc.)
• Delay in obtaining permits from municipality
• Hot weather effect on construction activities
• Rain effect on construction activities
• Unavailability of utilities in site (like water, electricity, telephone, etc.)
• Effect of social and cultural factors
• Traffic control and restriction at job site
• Accident during construction
• Differing site (ground) conditions
• Changes in government regulations and laws
• Delay in providing services from utilities (like water, electricity)
• Delay in performing final inspection & certification by a third party